2. BACKGROUND INFORMATION

This chapter presents definitions of key terminologies related to streetlight design. It also discusses fundamental concepts related to lighting.

2.1 DEFINITIONS

The definitions provided here are broadly classified in two different groups: 1) optics, and 2) streetlight hardware. The definitions in each group are described below.

2.1.1 Optics

Average Initial Illuminance: The average level of horizontal illuminance on the pavement area of a traveled way at the time the lighting system is installed with new lamps and clean luminaries; expressed in average footcandles (lux) for the pavement area.

Average Maintained Illuminance: The average level of horizontal illuminance on the pavement when the output of the lamp and luminaire is reduced by the maintenance factors; expressed in average footcandles (lux) for the pavement area.

Candela: The unit of luminous intensity. The term “candle” was formerly used.

Candlepower: The luminous intensity in a specified direction; which is expressed in candelas.

Color rendering: A general expression used for the effect of a light source on the color appearance of objects in conscious or subconscious comparison with their color appearance under a reference light source.

Color Rendering Index (CRI): A measure of the color shift the objects undergo when illuminated by the light source as compared with those same objects when illuminated by a reference source of comparable color temperature.

Cutoff angle (of a luminaire): The angle that is measured up from nadir, between the vertical axis and the first line of sight at which the bare source is not visible.

Footcandle: The illuminance on a one-square-foot surface in area, on which there is a light flux of one lumen that is uniformly distributed. One footcandle = 10.76 lux.

Foot Lambert: The uniform luminance of a surface emitting or reflecting light at the rate of one lumen per square foot. It is a unit of luminance or brightness.

Glare: The sensation produced within the visual field by luminance that exceeds the eye’s ability to adapt. This can cause annoyance, discomfort, or loss in visual performance and visibility.

a. **Nuisance glare:** It is known as annoyance glare that causes complaints. The Illuminating Engineering Society of North America (IESNA) defines nuisance glare as the "light shining in my window" phenomenon.
b. **Discomfort glare:** The glare that causes physical discomfort but does not keep the viewer from seeing an object.
c. **Disability glare:** The effect of a bright light source that causes the stray light to scatter in the eye. The stray light obscures the primary image on the retina and restricts the viewer from seeing the object.

Illuminance: The time rate of flow of light is defined as luminous flux. Illuminance is the density of the luminous flux incident on a uniformly illuminated surface.

Light Pollution: The haze or "glow" that reduces the ability of a person to view the nighttime sky. It is the stray light from luminaire, which is directed up into the skies; it is also referred to as "sky glow."

Light Trespass: The light from a luminaire that falls onto neighboring space, or into windows of adjacent building. It is also referred to as "spill light."

Louver (or louver grid): A series of baffles used to shield a source at certain angles, to either absorb or block unwanted light, or to reflect or redirect light. They are usually arranged in a geometric pattern.

Lumen: A unit of measure of the quantity of light. The amount of light that falls on an area of one square foot, every point of which is one foot from the source (i.e., a sphere) of one candela (candle), is defined as one lumen. A light source of one candela emits a total of 12.57 lumens.

Lumen depreciation: The decrease in lamp lumen that occurs as a lamp is operated until failure.

Luminaire: A complete lighting unit consisting of a lamp or lamps together with the parts designed to distribute the light, to position and protect the lamps and ballast (where applicable), and to connect the lamps to the power supply.

Luminaire dirt depreciation: The dirt or dust that accumulates on luminaires decreasing the total output of light, lowering the overall efficiency of the system.

Luminaire efficiency: The ratio of luminous flux (lumens) emitted by a luminaire to that emitted by the lamp or lamps used therein.

Luminance: The luminous intensity of a surface in a given direction per unit of that surface as viewed from that direction.

Luminous Efficacy: The rate of converting the electrical energy into visible energy, which is measured in lumens per watt.

Lux: The International System (SI) unit of illuminance. It is defined as the amount of light on a surface of one square meter all points of which are one meter from a uniform source of one candela. One lux = 0.0929 footcandle.

Uniformity of Illuminance: The ratio of average footcandles (lux) of illuminance on the surface area to the footcandles (lux) at the point of minimum illuminance on the pavement. It is generally called the uniformity ratio.

Uniformity of Luminance: The Average-Level-To-Minimum Point method uses the average luminance on a surface of the roadway design area between two adjacent luminaries, divided by the lowest value at any point in the area. The Maximum-To-Minimum Point method uses the maximum and minimum values between the same adjacent luminaires. The uniformity of luminance (avg/min and max/min) considers the traveled portion of the roadway, except for divided highways that has different designs on each side.

Uplight: The percentage of lamp lumens directed at or above 90 degrees from a luminaire.

Veiling Luminance: A luminance superimposed on the retinal image that reduces its contrast, resulting in visual performance and decreased visibility; produced by bright areas in the visual field.

2.1.2 Streetlight Hardware

Ballast: A coil of wire and/or related electronic components used to limit the amount or electric current flowing through a lamp. Almost all lamps used in streetlighting require ballasts except incandescent lamps.

Base: A lower part of a streetlight pole that supports the shaft.

Bracket (mast arm): An attachment to a pole from which a luminaire is suspended.

Breakaway Base: A base designed to yield when struck by a vehicle, thereby minimizing injury to the occupants of the vehicles and damage to the vehicle itself.

Head: The part of the luminaire that holds the lamp socket and mounting hanger or collar. The assembly will be referred as either the head or the body, when the mounting collar is part of, or attached directly to, the reflector housing, as in a clamshell style.

High-Mast Lighting: The illumination of a large area by means of a group of luminaires mounted on fixed orientation at the top of a high mast, generally 65 ft or higher.

Lamppost: A standard support provided with the necessary internal attachments for wiring and the external attachments for the bracket and luminaire.

Photocontrol: The device that is usually cylindrical and the size of a tin can, contains a light sensitive element and other electromechanical or electronic components to turn the lights on at night and off during the day.

Reflector: Any polished or light colored object used in optical control to change the direction of light rays as opposed to just block or absorb it.

Refractor: A transparent panel or dish that also serves as a lamp cover and has molded ridges to bend the light in desired directions.

Streetlight Pole: A pole used for the purpose of supporting street luminaire(s). The luminaire(s) may be either installed on (upright poles) or suspended from the pole (pendant poles). Figure 1 shows the different components of poles. The upright poles include Nos. 18, 16, 14 and Twin-20; and the pendant poles include Cobrahead, 5A Alley Pole and Teardrop.

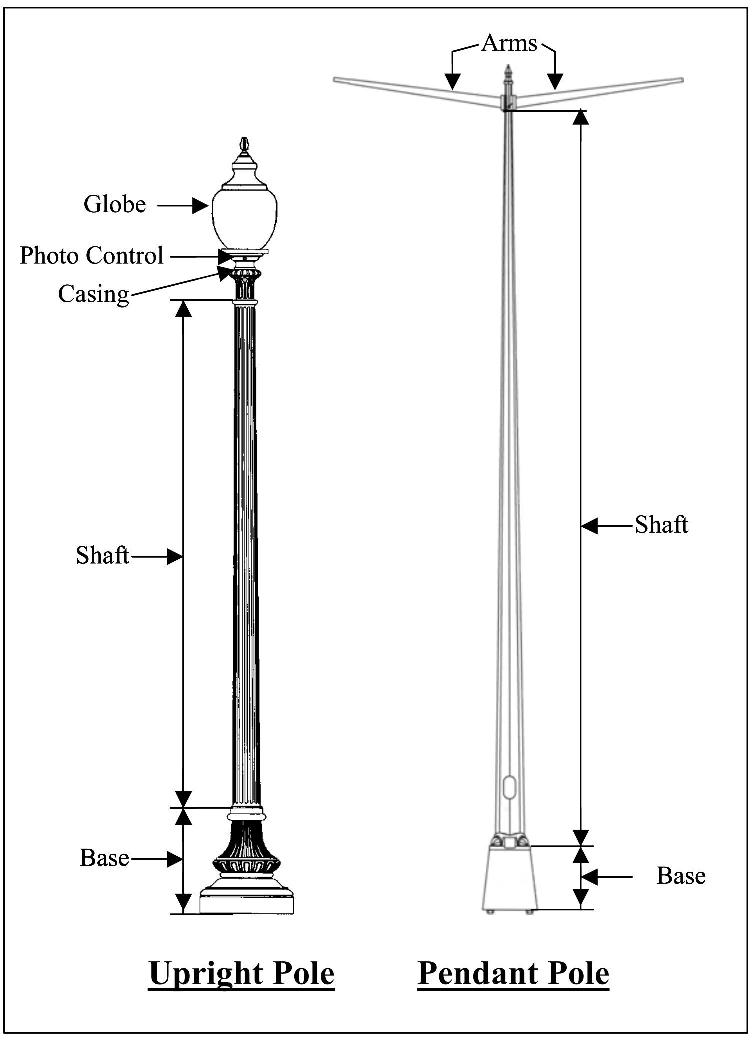


Figure 1. Components of Streetlight Poles - Upright and Pendant

2.2 AASHTO ROADWAY LIGHTING REQUIREMENTS

American Association of State Highway and Transportation Officials (AASHTO) and Illumination Engineers Society (IES) of North America recommend Table 1 and Table 2 as the guidelines for lighting design. These tables establish some threshold values, which a roadway lighting designer meets by using either the illuminance technique or the luminance technique.

Table 1. AASHTO & IES-Suggested Maintained Luminance Values for Roadways

Roadway Classification		Luminance				Veiling Luminance Ratio
		L_{avg}		Uniformity		
		(cd/m^2)	foot-lamberts	L_{avg}/L_{min}	L_{max}/L_{min}	$L_{v(max)}/L_{avg}$
Freeway Class A [a]		0.6	0.17	3.5:1	6:1	0.3:1
Freeway Class B [a]		0.4	0.12	3.5:1	6:1	
Expressway [b]	Commercial	1.0	0.29	3:1	5:1	0.3:1
	Intermediate	0.8	0.23	3:1	5:1	
	Residential	0.6	0.17	3.5:1	6:1	
Major [b]	Commercial	1.2	0.35	3:1	5:1	0.3:1
	Intermediate	0.9	0.26	3:1	5:1	
	Residential	0.6	0.17	3.5:1	6:1	
Collector [b]	Commercial	0.8	0.23	3:1	5:1	0.4:1
	Intermediate	0.6	0.17	3.5:1	6:1	
	Residential	0.4	0.12	4:1	8:1	
Local [b]	Commercial	0.6	0.17	6:1	10:1	0.4:1
	Intermediate	0.5	0.15	6:1	10:1	
	Residential	0.3	0.09	6:1	10:1	
Alleys [b]	Commercial	0.4	0.12	6:1	10:1	0.4:1
	Intermediate	0.3	0.09	6:1	10:1	
	Residential	0.2	0.06	6:1	10:1	

[a] Source: *The IESNA Lighting Standard Handbook, Ninth Edition*, IES, 2000. Illuminating Engineering Society of North America

[b] Source: *An Informational Guide for Roadway Lighting*, AASHTO, 1984.

Table 2. AASHTO and IES-Suggested Maintained Illuminance Values for Roadways

Roadway Classification		Average Illuminance Pavement Classification						Uniformity avg/min
		R1		R2 & R3		R4		
		Foot-candles	Lux	Foot-candles	Lux	Foot-candles	Lux	
Freeway Class A [a]		0.6	6	0.8	9	0.7	8	3:1
Freeway Class B [a]		0.4	6	0.6	6	0.5	5	
Expressway [b,c]	Commercial	0.9	10	1.3	14	1.2	13	3:1
	Intermediate	0.7	8	1.1	12	0.9	10	
	Residential	0.6	6	0.8	9	0.7	8	
Major [b]	Commercial	1.1	12	1.6	17	1.4	15	3:1
	Intermediate	0.8	9	1.2	13	1.0	11	
	Residential	0.6	6	0.8	9	0.7	8	
Collector [b]	Commercial	0.7	8	1.1	12	0.9	10	4:1
	Intermediate	0.6	6	0.8	9	0.7	8	
	Residential	0.4	4	0.6	6	0.5	5	
Local [b]	Commercial	0.6	6	0.8	9	0.7	8	6:1
	Intermediate	0.5	5	0.7	7	0.6	6	
	Residential	0.3	3	0.4	4	0.4	4	
Alleys [b]	Commercial	0.4	4	0.6	6	0.5	5	6:1
	Intermediate	0.3	3	0.4	4	0.4	4	
	Residential	0.2	2	0.3	3	0.3	3	
Sidewalks [b]	Commercial	0.9	10	1.3	14	1.2	13	3:1
	Intermediate	0.6	6	0.8	9	0.7	8	4:1
	Residential	0.3	3	0.4	4	0.4	4	6:1
Pedestrian Ways and Bicycle Lanes [d]		1.4	15	2.0	22	1.8	19	3:1

[a] Source: *The IESNA Lighting Standard Handbook, Ninth Edition*, IES, 2000. Illuminating Engineering Society of North America
[b] Source: *An Informational Guide for Roadway Lighting*, AASHTO, 1984.
[c] Both mainline and ramps. Expressways with full control of access are covered in the section on Freeways.
[d] This assumes a separate facility. Facilities adjacent to a vehicular roadway should use the illuminance or luminance levels for that roadway.

AASHTO is currently updating the design guide and Table 3 provides the suggested lighting design values proposed in the AASHTO's Roadway Lighting Design Guide Ballot Draft version.

Generally, the illuminance technique is used for streetlighting design. The selection of threshold values is based upon several factors, as stated below:

1. Functional classification of the facility (e.g., arterial, collector, etc.)
2. Type of land use (e.g., commercial, residential, etc.)
3. Classification of pavement (e.g., R1, R2, etc., based on type of pavement material)

Table 3. AASHTO Suggested Maintained Illuminance and Luminance Values for Roadways

Roadway and Walkway Classification	Off-Roadway Light Sources	Average Maintained Illuminance								Minimum Illuminance	Illuminance Uniformity Ratio	Average Maintained Luminance				Veiling Luminance Ratio
		R1		R2		R3		R4				L_{avg}		Uniformity		
	General	(Lux)	Foot-candles	(Lux)	Foot-candles	(Lux)	Foot-candles	(Lux)	Foot-candles	(Lux)		cd/m^2	Foot-lamberts	L_{avg}/L_{min}	L_{avg}/L_{min}	(max) [c]
	Land Use	(min)		(min)		(min)		(min)			(max) [b]	(min)		(max)	(max)	$L_{v(max)}/L_{avg}$ [d]
Urban Principal Arterials																
Interstate	Commercial	8 to 12	0.7 to 1.1	8 to 12	0.7 to 1.1	8 to 12	0.7 to 1.1	8 to 12	0.7 to 1.1	2	3:1 or 4:1	0.4 to 0.6	0.12 to 0.17	3.5:1	6:1	0.3:1
	Intermediate	8 to 10	0.7 to 0.9	8 to 10	0.7 to 0.9	8 to 10	0.7 to 0.9	8 to 10	0.7 to 0.9	2	3:1 or 4:1	0.4 to 0.6	0.12 to 0.17	3.5:1	6:1	0.3:1
	Residential	6 to 8	0.6 to 0.7	6 to 8	0.6 to 0.7	6 to 8	0.6 to 0.7	6 to 8	0.6 to 0.7	2	3:1 or 4:1	0.4 to 0.6	0.12 to 0.17	3.5:1	6:1	0.3:1
Other freeways	Commercial	10	0.9	14	1.3	14	1.3	13	1.2	As uniformity ratio allows	3:1	1.0	0.29	3:1	5:1	0.3:1
	Intermediate	8	0.7	12	1.1	12	1.1	10	0.9		3:1	0.8	0.23	3:1	5:1	0.3:1
	Residential	6	0.6	9	0.8	9	0.8	8	0.7		3:1	0.6	0.17	3.5:1	5:1	0.3:1
Other Principal Arterials (partial or no control of access)	Commercial	12	1.1	17	1.6	17	1.6	15	1.4		3:1	1.2	0.35	3:1	5:1	0.3:1
	Intermediate	9	0.8	13	1.2	13	1.2	11	1.0		3:1	0.9	0.26	3:1	5:1	0.3:1
	Residential	6	0.6	9	0.8	9	0.8	8	0.7		3:1	0.6	0.17	3.5:1	6:1	0.3:1
Urban Minor Arterials																
	Commercial	10	0.9	15	1.4	15	1.4	11	1.0		4:1	1.2	0.35	3:1	5:1	0.3:1
	Intermediate	8	0.7	11	1.0	11	1.0	10	0.9		4:1	0.9	0.26	3:1	5:1	0.3:1
	Residential	5	0.5	7	0.7	7	0.7	7	0.7		4:1	0.6	0.17	3.5:1	6:1	0.3:1
Collector																
	Commercial	8	0.7	12	1.1	12	1.1	10	0.9		4:1	0.8	0.23	3:1	5:1	0.4:1
	Intermediate	6	0.6	9	0.8	9	0.8	8	0.7		4:1	0.6	0.17	3.5:1	6:1	0.4:1
	Residential	4	0.4	6	0.6	6	0.6	5	0.5		4:1	0.4	0.12	4:1	8:1	0.4:1
Local																
	Commercial	6	0.6	9	0.8	9	0.8	8	0.7		6:1	0.6	0.17	6:1	10:1	0.4:1
	Intermediate	5	0.5	7	0.7	7	0.7	6	0.6		6:1	0.5	0.15	6:1	10:1	0.4:1
	Residential	3	0.3	4	0.4	4	0.4	4	0.4		6:1	0.3	0.09	6:1	10:1	0.4:1
Alleys																
	Commercial	4	0.4	6	0.6	6	0.6	5	0.5		6:1	0.4	0.12	6:1	10:1	0.4:1
	Intermediate	3	0.3	4	0.4	4	0.4	4	0.4		6:1	0.3	0.09	6:1	10:1	0.4:1
	Residential	2	0.2	3	0.3	3	0.3	3	0.3		6:1	0.2	0.06	6:1	10:1	0.4:1
Sidewalks																
	Commercial	10	0.9	14	1.3	14	1.3	13	1.2		3:1	Use illuminance requirements				
	Intermediate	6	0.6	9	0.8	9	0.8	8	0.7		4:1					
	Residential	3	0.3	4	0.4	4	0.4	4	0.4		6:1					
Pedestrian Ways and Bicycle Lanes [a]	All	15	1.4	22	2.0	22	2.0	19	1.8		3:1					

Source: *Roadway Lighting Design Guide Ballot Draft*, AASHTO, 2004.
[a] Use R3 requirements for walkway/bikeway surface materials other than the pavement types shown.
[b] Higher uniformity ratios are acceptable for elevated ramps near high mast poles.
[c] Meet either the Illuminance design method requirements or the Luminance design method requirements and meet veiling luminance requirements for both the Illuminance and the Luminance design methods.
[d] $L_{v(max)}$ occurs at initial lumens, therefore, use L_{ave} initial, not L_{avg} maintained .

Note:
1 There may be situations when higher level of illuminance is justified.
2 Physical roadway conditions may require adjustment of spacing determined from the base levels of illuminance indicated above.

The factors used in the above tables are discussed below.

Functional Classification of the Facility

The following classifications are those recommended by the Illuminating Engineering Society of North America[1] and AASHTO[2].

1. **Freeway:** This is a divided major roadway with full control of access and with no crossing at grade. It applies to toll as well as non-toll roads.
   a. Freeway A: This designates roadways with greater visual complexity and high traffic volumes. This type of freeway is usually found in major metropolitan areas in or near the central core. It operates through much of the early evening hours of darkness at or near design capacity.
   b. Freeway B: This designates all other divided roadways with full control of access where lighting is needed.
2. **Expressway:** A divided major roadway for through traffic with partial control of access and generally at major crossroads with interchanges. Parkways are generally known as expressways for non-commercial traffic within parks and park-like areas.
3. **Major/Principal Arterial:** That part of the roadway system serving as the principal network for through traffic flow. The routes connect important rural highways entering the city and areas of principal traffic generation.
4. **Minor Arterial:** The roadway that provides relatively high speeds and least interference to through traffic flow with little or no access control. It provides direct access to abutting properties, have frequent at-grade intersections, have pedestrian movements along and across the roadway, accommodate bicyclist unless specifically limited and support public transportation.
5. **Collector:** The roadways servicing traffic between major and local roadways. These are roadways used mostly for traffic movements within residential, commercial, and industrial areas.
6. **Local:** The roadways used mainly for direct access to residential, commercial, industrial, or other abutting property. They do not include roadways that carry through traffic. The long local roadways are generally divided into short sections by collector roadway systems.
7. **Alley:** A narrow public ways within a block, which is generally used for vehicular access to the rear of abutting properties.
8. **Sidewalk:** A paved or otherwise improved areas for pedestrian use, located within the public street right-of-way, which also contains roadways for vehicular traffic.
9. **Pedestrian Walkway:** A public facility for pedestrian traffic not necessarily within the right-of-way of a vehicular traffic roadway. They include skywalks (pedestrian

[1] *American National Standard Practice for Roadway Lighting*, ANSI/IES RP-8.1983; Illuminating Engineering Society of North America.
[2] *Roadway Lighting Design Guide Ballot Draft,* AASHTO, 2004.

overpasses), subwalks (pedestrian tunnels), walkways giving access to parks or block interiors, and midblock street crossings.

10. **Bicycle lane:** A portion of roadway, or shoulder, or any facility that has been explicitly designated for the use by bicyclists.

Area Classifications

1. **Commercial**: A business development of a municipality where ordinarily there are many pedestrians during night hours. This definition applies to densely developed business areas outside, as well as within, the central section of a municipality. The area contains land use that attracts a relatively heavy volume of nighttime vehicular traffic or pedestrian traffic, or both, on a frequent basis.
2. **Intermediate**: Those areas often characterized by moderately heavy nighttime pedestrian activities such as in blocks having libraries, community recreation centers, large apartment buildings, industrial buildings, or neighborhood retail stores of a municipality.
3. **Residential**: A residential area, or a mixture of residential and small commercial establishments characterized by few pedestrians at night. This includes areas with single-family homes, townhouses, and small apartment buildings.

Certain land uses, such as office and industrial parks, may fit into any of the above classifications. The classification selected should be consistent with the expected nighttime pedestrian activities.

Road Surface Classification

The road surface classifications (as shown in Table 4) are used when designing a roadway lighting system. It is divided into four categories (R1, R2, R3 and R4) depending on the reflectance characteristics of the pavement. Each category has its own values of reflectance for specified angles.

Table 4. Road Surface Classification[3]

Class	Q_o*	Description	Mode of Reflectance
R1	0.10	Portland cement concrete road surface. Asphalt road surface with minimum of 15 percent of the aggregate composed of artificial brightener (e.g., Synopal) aggregates (e.g., labradorite, quartzite)	Mostly diffuse
R2	0.07	Asphalt road surface with an aggregate composed of a minimum 60 percent gravel (size greater than 10 millimeters) Asphalt road surface with 10 to 60 percent artificial brightener in aggregate mix. (Not normally used in North America)	Mixed (diffuse and specular)
R3	0.07	Asphalt road surface (regular and carpet seal) with dark aggregates (e.g., trap rock, blast furnace slag); rough texture after some month of use (typical highways)	Slightly specular
R4	0.08	Asphalt road surface with very smooth texture	Mostly specular

* Q_o = representative mean luminance coefficient

[3] Source: *American National Standard Practice for Roadway Lighting*. ANSI/IES RP-8.1983; Illuminating Engineering Society of North America.

2.3 LIGHT SOURCES

The light source is the most important element of illumination equipment. It is the principal determinant of visual quality, illumination efficiency, energy conservation, and the economic aspects of the lighting system. There are numerous types of light sources that are being used in roadway lighting. They include Mercury Vapor, Metal Halide, High-Pressure Sodium (HPS), Low-Pressure Sodium, and Fluorescent.

The light sources are generally compared on the basis of four major characteristics:

1. Luminous efficacy (i.e., the number of lumens produced per watt of energy)
2. Color rendition (i.e., color quality)
3. Lamp life (i.e., number of operating hours)
4. Optical control

As mentioned earlier, HPS, Metal Halide, Mercury Vapor, Fluorescent and Incandescent lamps are generally used. HPS is the most efficient option with a long life, while Metal Halide has an excellent color rendition. Incandescent and Mercury Vapor are being phased out. The comparison of various lamp types is shown in Table 5.

Table 5. Comparison of Lamps

Option	Method	Advantages	Disadvantages
Incandescent	▪ Lamps which produce light by using electric current to heat a filament	▪ Instant on ▪ Low initial cost ▪ Excellent color rendition ▪ Can be dimmed ▪ Compact in size	▪ Short life (500-5,000 hrs) ▪ Inefficient to operate ▪ High heat output
Fluorescent	▪ Lamps that pass electricity through a gas enclosed tube to create light ▪ Usually used indoor and in some cases for signage	▪ Twice the light and less than half the heat of an Incandescent bulb of equal wattage. ▪ Long life (10,000-15,000 hrs) ▪ Efficient ▪ Good color rendition	▪ Temperature sensitive
Mercury Vapor	▪ A high-intensity discharge device producing light by excitation of mercury vapors (or passing electricity through a gas) to emit a bluish white light	▪ Long life (16,000-24,000 hrs) ▪ Low initial cost	▪ Inefficient operation ▪ Light output drops over life (2-3 yrs) ▪ Delayed hot restart
Metal Halide	▪ High intensity discharge arc tube in which light is produced by radiation of exited Metal Halide	▪ Excellent color rendition ▪ Sparkling white light that imitates daylight conditions, used in sports stadiums, car dealer lots, etc. ▪ 100-watt bulb lasts 10K hrs ▪ Works well with CCTV	▪ Hot restart can take several minutes ▪ High initial cost ▪ Most expensive light to install and maintain
High Pressure Sodium	▪ High intensity discharge arc tube in which light is produced by radiation from sodium vapor operating under pressure	▪ Very long life (20K-28K hrs) ▪ Can cut through fog and allow greater visibility (used on street and parking lots) ▪ In some cases, it can be used with CCTV	▪ High initial cost of fixtures ▪ Hot restart can take several minutes

A summary of properties of various lamps is presented in Table 6. The number of hours the lamp remains functional is considered as the life of the lamp. The efficacy is a measure of the "efficiency" of a lamp, measured in lumens per watt (i.e., knowing how much light is given out for a given amount power input), allows comparisons of energy efficiency to be made. The Color Rendering Index (CRI) is a relative measure of the shift in surface color of an object when lit by a particular lamp, compared with how the object would appear under a reference light source of similar color temperature. The higher the CRI of the light source, the "truer" it renders color.

Table 6. Summary of Lamp Properties

Option	Life (hrs)	Efficacy (lpw)	Color Rendering Index	Color of light
High Pressure Sodium	20,000-24,000	50-110	≤40 (approx. 22)	Orange
Metal Halide	6,000-15,000	72-76	75-90	White
Mercury Vapor	16,000-24,000	30-50	40-60	Blue-White
Fluorescent	10,000-24,000	40-140	20-80	White

A lamp's lumen output declines rapidly during its life; therefore, a designer should initially provide more lumens than is required so that as the lamp declines with age, a sufficient amount of light is still available. Figure 2 shows typical lamp lumen depreciation over time for three light sources – Low Pressure Sodium (LPS), High Pressure Sodium (HPS) and Metal Halide Pulse Start Horizontal (MH).

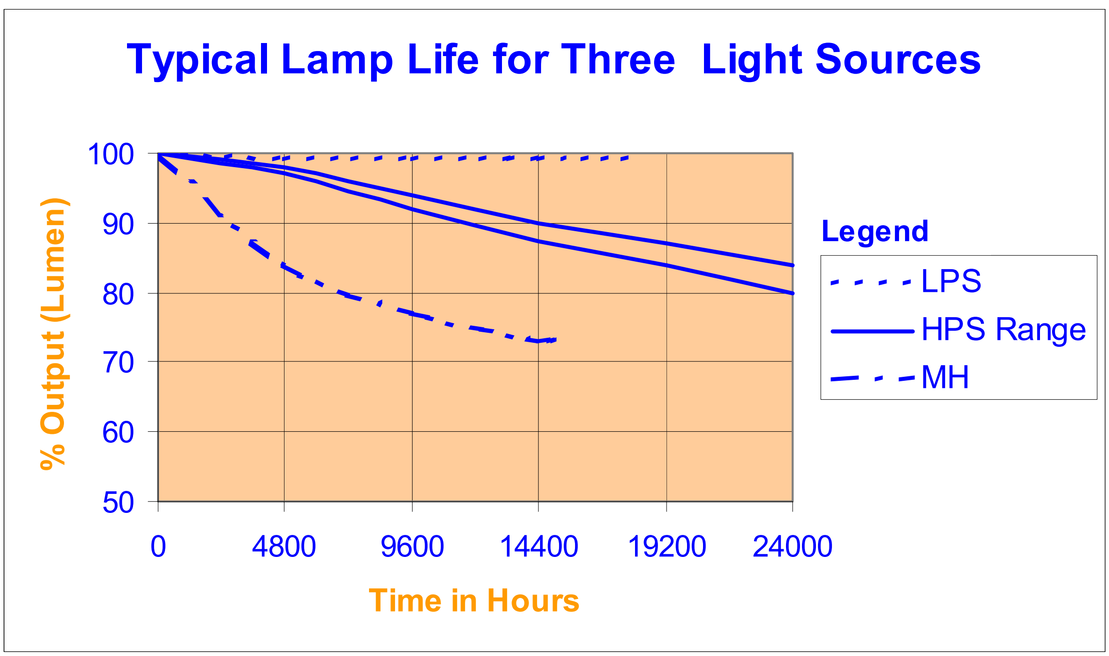


Figure 2. Typical Lamp Lumen Depreciation

Advances in HPS lamp technology have led to the development of a new color corrected HPS lamp. Color corrected HPS lamps are made by using optical coatings; however, the coating often gets burnt out. Even with greatly improved Color Rendering Index (about 80), the color corrected HPS lamp still delivers yellow light for sometime when the bulb is switched on, and is not as white as the Metal Halide. It has been further reported that the color coating becomes ineffective at about half-life of the lamp.

In Europe, induction lamps are widely used and have a number of advantages. It has a long life – 100,000 hours rated average life[4]. It provides a Color Rendering Index of 80+ CRI, which is almost twice as much as that of mercury vapor (45 CRI) and almost four times as much as that of HPS (21 CRI). Even though it has a higher initial cost, its long life reduces the operations and maintenance costs. Starting operation is instant with no flickering. The disadvantages include the unavailability of moderate to high wattage lamps. The lamp will not "burn out" but will just get so dim that it no longer supplies adequate light for a given application. Although it has a long life, the ballasts may fail sooner, requiring the replacement of both the lamp and the ballast.

2.4 POLES

There are four types of poles used for luminaire support; these are Fiberglass, Aluminum, Steel and Concrete poles. The advantages and disadvantages are discussed in Table 7. The District mostly uses steel poles and is phasing out Fiberglass.

Table 7. Comparison of Poles

Option	Advantages	Disadvantages
Fiberglass Pole	▪ Direct burial pole is easy to install, and requires no waiting for concrete to cure. Some fiberglass poles are available for mounting to an anchor base. ▪ Electrically non-conductive ▪ Corrosion resistant ▪ Fiberglass materials should be 'solid-core' so that scratches and gashes in the pole will be less noticeable ▪ Lower cost option than many metal poles ▪ Lighter, less expensive to ship to sites ▪ Should have above ground access door, otherwise it's a maintenance problem	▪ Needs to be painted every 15 years because the color fades with time ▪ Appears to be cheaper and less durable than metal poles ▪ Pole has texture that looks un-metallic if standard paint finish is applied. Smooth paint finishes help to get rid of turn marks ▪ Weed whackers beat up the base of fiberglass poles ▪ If not stored carefully, heat can warp the pole
Aluminum Pole	▪ Good quality appearance. Fluting and other relief details are easy options. ▪ Factory-installed paint finish often more durable than fiberglass pole finish. The pre-treatment and base coating of the pole is critical to paint and pole durability. ▪ With good-quality multi-stage paint finish in factory, corrosion is minimal, especially when low-copper aluminum alloy is used ▪ Moderate cost: Tapered aluminum poles are less expensive than straight aluminum poles in sizes greater than 14' ▪ Aluminum has scrap value at the end of it's life	▪ Electrically conductive ▪ More difficult to install than fiberglass because it requires anchor base

[4] Based on 11 hours average usage per day, 7 days a week.

Option	Advantages	Disadvantages
Steel Pole	▪ Low initial cost	▪ Electrically conductive ▪ Corrodes easily. Needs frequent painting ▪ More difficult to install because it requires anchor base ▪ Heavier to ship to jobsite than either aluminum or fiberglass poles
Concrete Pole	▪ Durable, non-corroding ▪ Electrically non-conductive ▪ Easy, direct burial installation, that requires no waiting for concrete to cure ▪ Several color options for appearance ▪ Can function as a barrier against vehicular traffic for pedestrians, but will not breakaway if struck by vehicle	▪ Non-traditional appearance (doesn't look like metal) ▪ Must be re-coated with preserving finish every 15 years ▪ Hard to add accessories such as banners or parking signs. Requires stainless steel bands around the pole unless pole is pre-drilled for these attachments. ▪ Limited number of appearance options beyond color and aggregate ▪ Higher initial cost than fiberglass or aluminum poles

2.5 PHOTOSENSOR

The streetlight has a photosensor that turns off when exposed to light and vice versa. There are two types of photosensors- button type and twist-lock. The button type photosensors need to be avoided as they have a high failure rate. This must be installed in the luminaire and should be done in the factory as the field personnel complain that it is too difficult and time consuming to install it in the field. The 'Twist-lock' photosensors are preferred and are mounted to bracket arms on the poles rather than the luminaire.

2.6 GLOBES

The Washington globes are made either of glass or plastic. The glass globes were originally being used, but were discontinued, as they are not safe. Therefore D.C. went from glass to plastic. The cost of a glass globe is approximately \$300, an acrylic globe is \$125 and a prismatic acrylic globe is \$200. The comparisons between the globes are shown in Table 8.

Table 8. Comparison of Globes

Option	Facts	Advantages	Disadvantages
Plastic (Acrylic) Globe	▪ 'DR Acrylic' is tougher form of acrylic that will not yellow from UV radiation. Not as resistant to breakage as polycarbonate. Excellent choice for both MH and HPS lamps. This impact resistant acrylic will last 10-15 years.	▪ Acrylic does not yellow with exposure to UV radiation from either daylight or lamps.	▪ Standard acrylic is easily cracked and broken, so it is not recommended to be used as post-top lighting
Plastic (Polycarbonate) Globe	▪ Seldom used with MH lamps because MH emits larger amount of UV rays than HPS lamps do. ▪ Polycarbonate lenses and globes have a life of only 5-10 years.	▪ Very tough form of plastic	▪ Yellows when expose to UV radiation and become brittle with time.
Glass Globe	▪ Plain Glass	▪ Very durable material that does not change color (yellow) over time	▪ Very heavy ▪ Not safe, as it could tear the cars tires or harm someone when broken.

2.7 LATERAL DISTRIBUTION PATTERNS

The Illuminating Engineering Society (IES) establishes a series of lateral distribution patterns designated as Types I, II, III, IV and V. Types I and V represent symmetric lighting distribution and the luminaires are usually mounted over the center of the roadway. Types II, III and IV are asymmetric distribution and the luminaires are usually mounted near the edge of the roadway. Type I applies to rectangular patterns on narrow street, Type II to narrow streets, Type III to street of medium width, Type IV to wide streets and Types V to areas where light is to be distributed evenly in all directions. These are illustrated in the Figure 3.

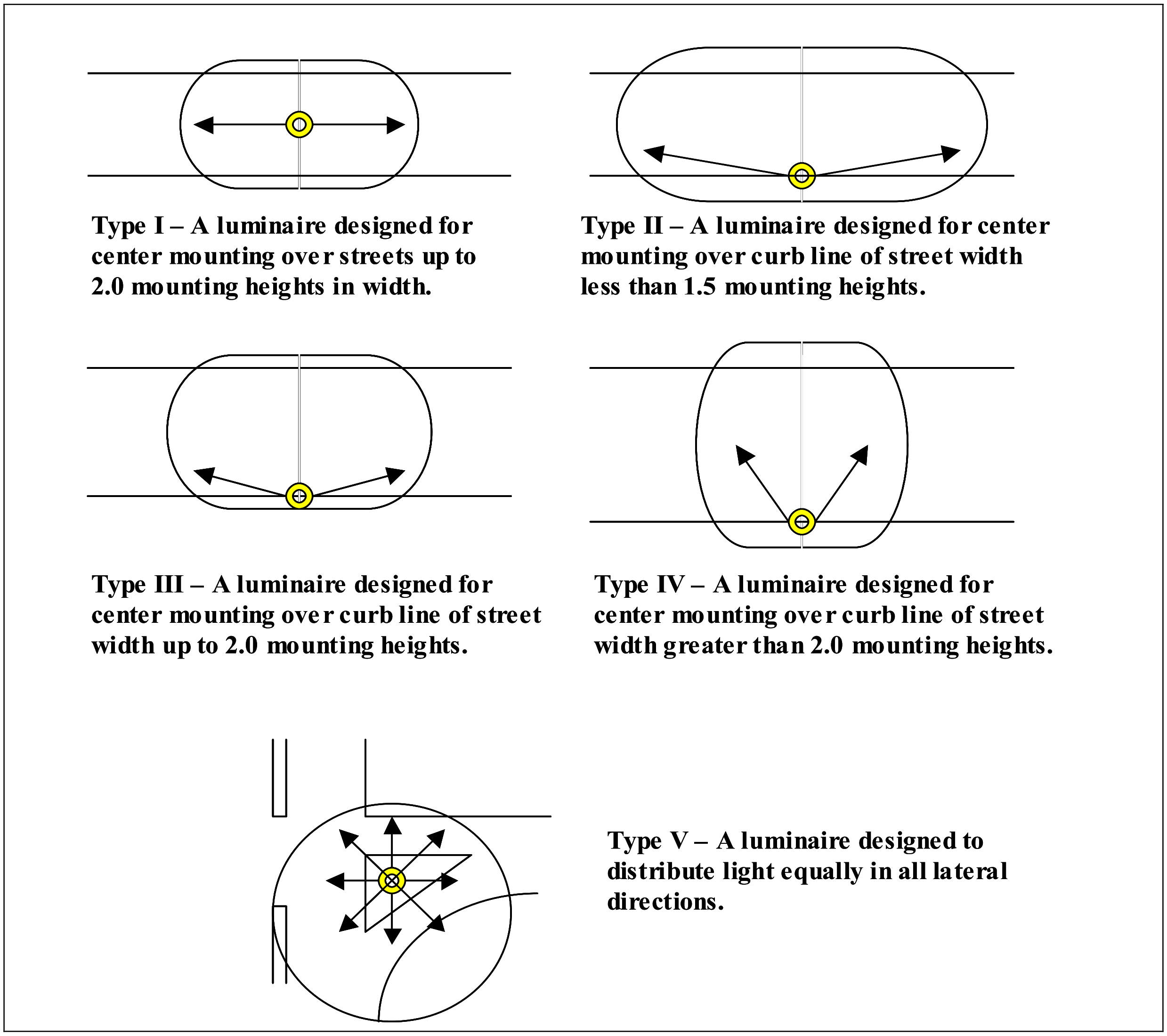


Figure 3. Type of Lighting Distribution[5]

2.8 POLE PLACEMENT CONFIGURATIONS

The luminaire placement is an integral part of an effective street-lighting design. The luminaires are mounted at a given height above the roadway, depending on the lamp output and characteristics of the roadway to be lighted at specific points along the roadway. Roadways with no medians may have the luminaires installed in a "house-side" location, which may be further described as a "one-side" system, a "staggered" system, or an "opposite" system. Roadways with wide medians and barriers may have the luminaire installed on a "median lighting" system, which provides very effective lighting at less cost because of the savings in luminaire supports and electrical conductors. The pole can be placed in various configurations as shown in Figure 4.

[5] Source: *American National Standard Practice for Roadway Lighting.* ANSI/IES RP-8.1983; Illuminating Engineering Society of North America.

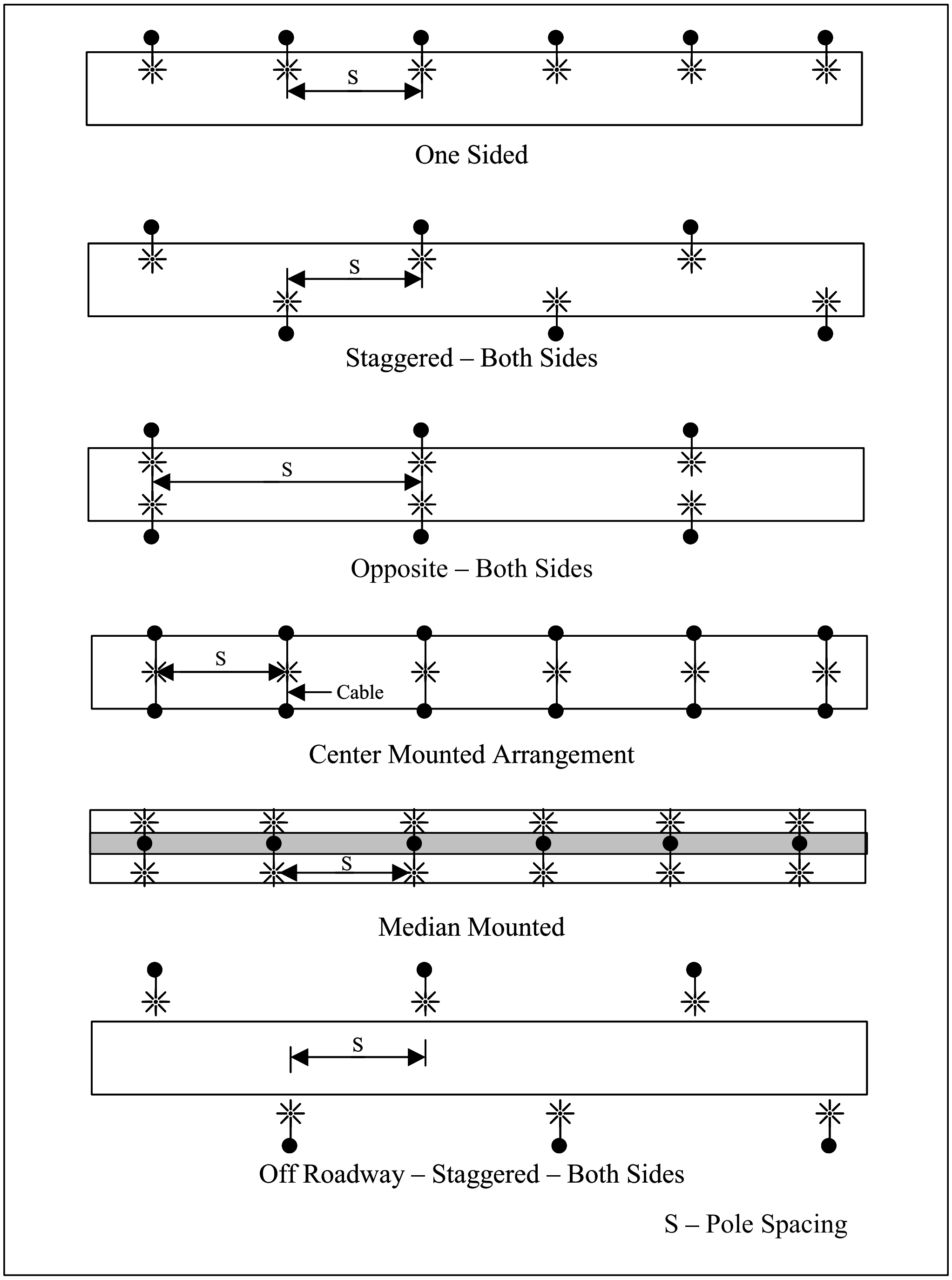


Figure 4. Typical Mounting Configurations[6]

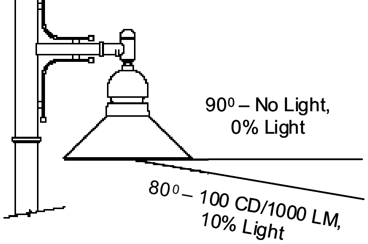
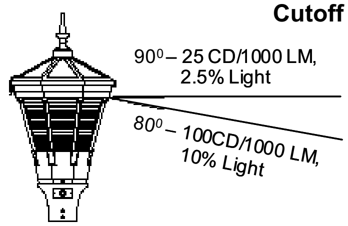
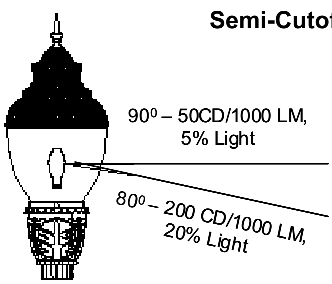
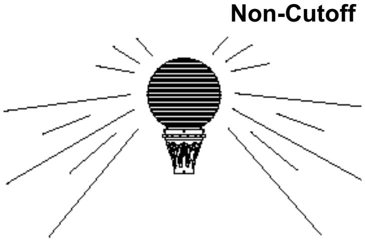
2.9 CUTOFF FIXTURES

It is important to control the distribution of light flux emission above the beam of maximum candlepower. At higher vertical angles, light flux emission generally contributes substantially

[6] Source: *Roadway Lighting Handbook,* Washington, DC, U.S. Department of Transportation, 1983.

to increased pavement brightness, but it also contributes greatly to increased disability and discomfort glare. The light flux emission above the beam of maximum candlepower needs to be controlled to achieve balanced performance. The categories of control are presented in Table 9 with some facts, advantages and disadvantages of each option.

Table 9. Comparison of Cutoff Levels

Option	Facts	Advantages	Disadvantages
Full Cutoff 	▪ A luminaire light distribution with zero candela (intensity) at an angle of 90° or above. ▪ The candela per 1000 lamp lumens is ≤ 100 (10%) at 80^o vertical angle ▪ No uplight allowed	▪ Perceived reduction in 'sky glow' ▪ Excellent light control at property line ▪ Limits spill light ▪ Reduces perceived glare	▪ Reduces pole spacing, increases pole and luminaire quantity ▪ Least cost effective of all cutoff categories ▪ Concentrated down light component results in maximum reflected uplight ▪ Decreased uniformity due to higher light levels under pole
Cutoff 	▪ A luminaire light distribution where the candela per 1000 lumens is ≤ 25 (2.5%) at an angle of 90$^°$ or more. ▪ The candela per 1000 lamp lumens does not exceed 100 (10%) at a vertical angle of 80^o. ▪ 0% to 16% uplight	▪ Small increase in high-angle light compared to full cutoff ▪ Good light control at property line ▪ Potential for increased pole spacing and lowering overall power consumption when compared to full cutoff	▪ Can allow uplight, a problem where uplight is not desired ▪ Light control at property line less than full cutoff ▪ Higher amount of reflected light off pavement can contribute to sky glow
Semi-Cutoff 	▪ A luminaire light distribution where the candela per 1000 lumens is ≤ 50 (5%) at 90^o angle or above. ▪ The candela per 1000 lamp lumens is ≤ 200 (20%) at 80^o vertical angle ▪ 1% to 32% uplight	▪ Potential for increased pole spacing and lowering overall power consumption when compared to full cutoff ▪ High angle light accents taller surfaces ▪ Less reflected light off pavement than cutoff luminaries ▪ Vertical illumination increases pedestrian security and safety	▪ Greater potential for direct uplight component than cutoff ▪ Light trespass a concern near residential areas ▪ Increased high angle light compared to cutoff
Non-Cutoff 	▪ A luminaire light distribution there is no candela restriction at any angle. ▪ No restriction on uplight	▪ Potential for increased pole spacing and lowering overall power consumption when compared to full cutoff ▪ Accents taller surfaces ▪ Highest vertical illumination increases pedestrian safety & security ▪ Potential for excellent uniformity ▪ Least amount of reflected light off pavement ▪ 'Open visual environment' provides vertical surface visibility	▪ Greater potential for direct uplight component than cutoff ▪ Least control of uplight ▪ Increased high angle light compared to cutoff

Source: HOLOPHANE